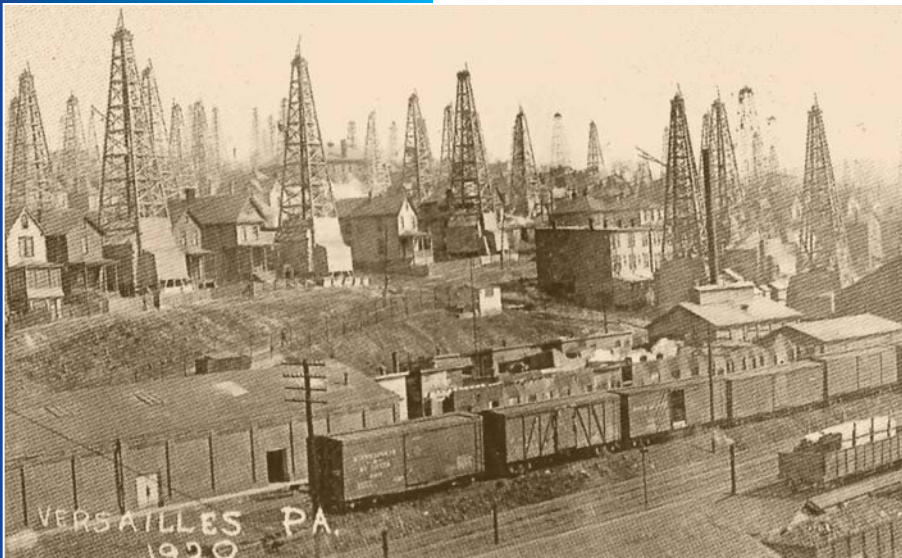


# Methane Emissions Project

**Borough of  
Versailles, Pennsylvania**



## **EXECUTIVE SUMMARY**

**October 31, 2007**

*Prepared by*

**National Energy Technology Laboratory**



## **DISCLAIMER**

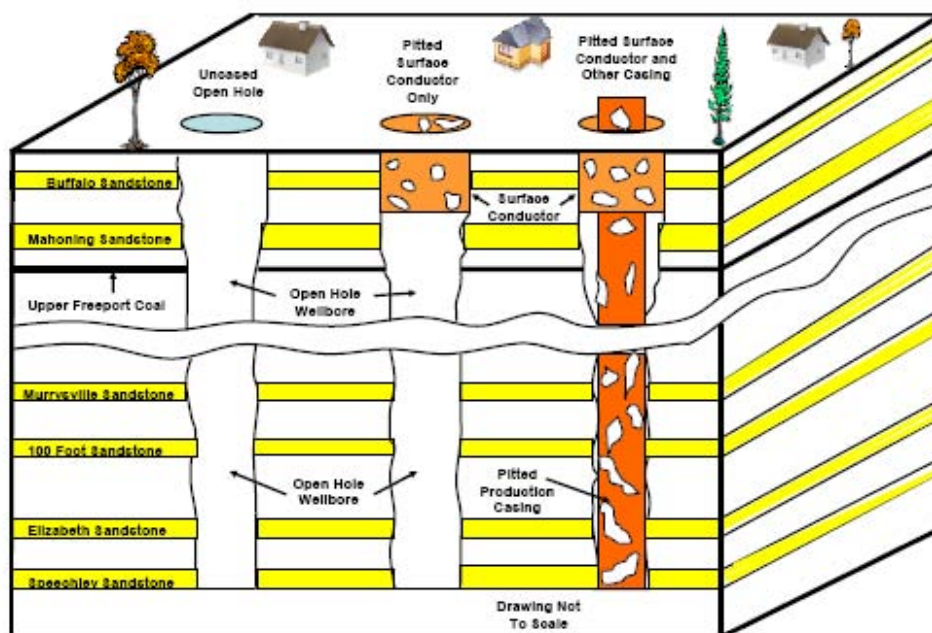
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Cover Photo: Versailles, PA, circa 1920 (Photo courtesy of Mrs. Josephine Cindric).

# Executive Summary

## Background

During the boom period from 1919 through 1921, over 600 natural gas wells were drilled as part of the McKeesport Gas Field. The primary target reservoir was the Speechley sandstone at a depth of approximately 3,000 feet, although a few wells were drilled to the overlying Elizabeth sandstone at the southern end of the Borough near Boston Bridge. The gas boom times saw interests in wells being bought and sold on the street corners of Versailles Borough, and neighbor pitted against neighbor as each tried to be the first to obtain the gas underlying their property, often on lots only 25 feet wide. As a result, over 175 wells were drilled in the Borough of Versailles. Some wells produced little or no gas and were abandoned without placing casing (steel pipe) in them. Others produced for only a few years as over-drilling and over-production rapidly depleted the reservoirs. These wells were cased, but were left abandoned and unplugged after production ceased. During World War II, the call for scrap steel resulted in the removal of the internal components of the abandoned steel casings and wellheads (well piping and valves above ground level). Again the wells were left abandoned and unsealed, but this time, there were fewer casings or wellheads remaining to mark the wells on the surface; the wells were just covered with dirt. This left three types of abandoned wells in Versailles Borough: wells that were never cased; wells with only the surface conductor (an external steel casing) left, which they could not pull from the ground, and; wells with the surface conductor and some of the original production casing. These three types of wells are shown in Figure 1.



**Figure 1.** Three types of abandoned wells found in Versailles Borough, and key geologic formations.

Construction boomed after the war – soldiers returned to work, started families, and homes and businesses were built adjacent to or over the now uncased/open wells. Methane gas has been reported to be leaking within and adjacent to local Versailles Borough residences and businesses since 1963, resulting in some residents being evicted from their homes until the problem could be corrected or, in extreme cases, condemnation of some structures. Previous investigations have been limited to surface findings and installation of methane removal vents, and did not delve into the actual subsurface source of the problem. As an added complication, some of the methane vents installed as a result of the previous studies have been removed or have deteriorated to the point of ineffectiveness.

In 2005, U.S. Representative Mike Doyle, Democrat, Pennsylvania's 14<sup>th</sup> District, secured federal funding for a study to determine how to potentially eliminate the threat to public safety presented by natural gas leaks in the Borough of Versailles. Because of its research expertise in geological science, the U.S. Department of Energy's National Energy Technology Laboratory (NETL) was given the task of developing a set of potential remediation recommendations. In order to do this, it was necessary to:

- define the extent of the problem,
- understand the physical and geological setting,
- determine the source(s) of natural gas leakage,
- evaluate potential migration pathways, and
- locate old gas wells within the Borough.

In carrying out this study, NETL collaborated with Research and Development Solutions (RDS, NETL's technical support contractor), the University of Pittsburgh, the Pennsylvania Department of Environmental Protection (PA DEP), private industry, and local government officials.

## **Approach**

The study approach involved investigating and characterizing the subsurface and surface to acquire a better understanding of this complex setting. Abandoned and improperly plugged boreholes from gas wells, dating back to the early 20<sup>th</sup> century, linked the geological formations underlying Versailles Borough. A number of investigations were conducted, including geophysical surveys (seismic and magnetic technologies), literature and newspaper searches, examination of historic maps and photographs, analyses of soil maps, meetings with local oil and gas industry personnel, personal interviews with Borough residents and officials, creation of maps and databases, gas analyses from existing vents and wells, downhole video camera examination of three abandoned gas wells, and searching for unknown gas leaks and hidden wells.

After discussions with Borough Council members and local residents, it was determined that the study area would be limited to the area within the Borough where known methane gas leakage existed. This area is roughly one-half-mile long by one-quarter-mile wide, bounded to the north by the McKeesport city limits, to the east by Walnut Street, to the south by the Boston Bridge, and to the west by the Youghiogheny River. Gas emissions have not been reported for the area of Versailles Borough east of Walnut Street. During the gas boom, this area was more rural and had

larger plots of land with fewer wells. Many of these wells were outside the productive area of the Speechley sandstone and never produced gas.

## **Study Findings**

Subsurface seismic investigations indicated the possible presence of some gas remaining in the original target reservoir, the Speechley sandstone, at a depth of approximately 2900 feet. This is typical for commercial operations. Shallow three-dimensional seismic surveys within the Borough also indicated the possible presence of near-surface gas pockets in the area of known methane gas leaks. However, no indications of potential commercial quantities of natural gas were found. Also, no faults or major fracture systems were identified, though some indications of fracture zones were observed beneath the river sediment.

Analyses of gas samples taken from the vents and wells in the Borough and data from PA DEP indicated that the gas reaching the surface is likely a natural gas mixture from various depths, possibly including gas from the originally exploited deeper strata, an intermediate zone that may have been used in the past for commercial natural gas storage, and/or the overlying coal beds, which are known to have gas in them. Gas from deeper underground has migrated upwards and seeped into shallower formations, such as the Upper Freeport coal seam and the Buffalo sandstone. Abandoned and improperly plugged wellbores appear to be the primary vertical migration pathways for the stray hydrocarbon gas, usually producing a point-source of gas at the surface. As mentioned, many of the wellbores have lost their surface exposure due to construction of buildings and surface facilities (e.g., above-ground swimming pools, porches, walkways, etc.), partial plugging by the landowner, or placement of fill over the well.

Upper Freeport coal was deep mined north and east of the Borough in the Hubbard Mine from the early 1920's until the early 1960's. There was no record of the mine extending under the area currently experiencing methane leakage, nor was there any visual evidence from borehole camera work – solid coal was always encountered. The first reported presence of gas leaking into structures in Versailles was in 1963, near the original coal mine opening. The Upper Freeport coal seam is known to be very gassy, and explosions are known to have occurred in the mine while it was being operated, though, during operation, most of the methane gas would have been removed by the ventilation system. It is not known whether gas in the mine was coal bed methane or gas that migrated vertically up old wellbores. Water was also removed as part of mining operations. Draining of water from the adjacent formations and possibly the coal underlying Versailles Borough may have allowed these formations to be charged with gas migrating from the abandoned vertical wellbores. Once mining ended and the mine opening was sealed, the mine began to flood with water and methane began to accumulate. The gas may, over time, have migrated upwards along the Murrysburg Anticline (a slight arch in the geologic formations) underlying Versailles. The anticline crests under Versailles, creating a place for gas to accumulate.

NETL conducted detailed surveys over about two-thirds of the study area, using a magnetometer and a highly sensitive methane and light gaseous hydrocarbon leak-detection system to look for abandoned well locations. The remainder of the area was either occupied by structures, or was inaccessible due to terrain/obstacles or the landowners' wishes. The magnetometry method

NETL uses can detect steel well casings, even if only the external segment remains, and has been proven to be extremely accurate at other sites. Fifty-two very strong magnetic signals were detected in the surveyed portion of the study area (Figure 2) and all of these 52 anomalies are suspected to be unmarked abandoned wells. Excavation of one of the anomalies revealed an abandoned well 2-3 feet below the surface, but only excavation of each site can positively confirm the presence of an abandoned well.

The open wellbores provide a vertical pathway for gas to migrate into permeable geologic formations near the surface, into the soil layers, and eventually into either the atmosphere or building foundations. Gas coming up old wells has a very low surface pressure (3.5 pounds per square inch, psi) and, in most cases, low production rates, less than 10 cubic feet per hour ( $\text{ft}^3/\text{hr}$ ). NETL measured a total of about  $70 \text{ ft}^3/\text{hr}$  emerging from all existing vents and wells prior to the opening of two abandoned wells. One vented well, located on the 4800 block of Second Street, was producing  $50 \text{ ft}^3/\text{hr}$  (1.2 Mcf/day) of the total  $70 \text{ ft}^3/\text{hr}$ . During dry weather, the gas can migrate directly into the atmosphere over a wide area through the soil. However, during wet or frozen conditions, saturated soil pores can block this low pressure migration. The gas then follows the path of least resistance; wellbores, natural fracture systems, and other permeable zones gather higher concentrations of methane. As a result, the few permeable zones that connect to the atmosphere will emit higher methane concentrations during such periods. This is why local residents noticed that gas levels in structures were worse during wet weather conditions. Similarly, during periods of high barometric pressure, the low-pressure stray hydrocarbon gas can be retained in the soils and underground rock strata.

Fourteen of the 52 sites with magnetic anomalies were found to be leaking stray hydrocarbon gas (Figure 2). Initial reports of stray hydrocarbon gas problems in the study area had indicated only two primary areas of concern – the 4300 block of Walnut and Third Streets and the 4700 and 4800 blocks of Second Street and Penn Way. The 14 unmarked and apparently leaking abandoned wells were found between these two areas. Most of the methane leakage determined from plume studies (transient methane gas in the air around Versailles carried by the wind) was associated with a known vent or one of these 14 wells. In addition, there were trace levels of methane not associated with wells and vents; those that could be traced back to a source were associated with likely sources of sewer gas (e.g., manhole covers) and judged not to be of concern.

Two old wells were reopened and accumulated debris was cleaned out to below the Upper Freeport coal seam to determine the source of the gas. Video surveys of the water-filled portion of the well on Walnut Street showed gas bubbling from a cleat (a crack) near the base of the Upper Freeport coal seam. Gas analysis confirms that the gas is methane. Lack of gas flow or pressure on the annulus side of the installed casing suggests that gas production is limited solely to the Upper Freeport coal in this area, and that the gas has not migrated to any of the overlying formations. However, in the well near the Borough garage, the gas appears to be entering the wellbore from the Buffalo sandstone, a unit less than 20 feet from the surface and more than 100



**Figure 2.** Suspected unmarked abandoned wells located using magnetic methods and methane detection.

feet above the Upper Freeport coal seam. This suggests that at least some old wellbores under the Borough are vertical conduits for gas from underground and that the gas has permeated into and migrated laterally into the more permeable strata and soil layers. There is no way of determining which wellbores are being sourced from deeper formations and which are being sourced by shallower formations without opening and cleaning out all of the wellbores. This would be impossible at some sites and impractical at others due to the size of the lots and the presence of structures immediately adjoining some of the wells.

A down-hole video survey was also run on the well at 4307 Third Street, which was not one of the cleaned-out wells, but had been a stray gas source in the past, causing temporary evictions. Methane gas problems associated with this well appear to be related to gas coming up the back (annulus) side of the smaller diameter casing – left in the hole to a depth of 44 feet. At this point, the smaller casing is separated from the larger (6-inch) surface casing. The well currently has an electric blower attached to the vent, which helps the gas move up the well and into the atmosphere; however, gas could still be leaking into the geologic formations below a depth of 44 feet, because of the casing separation.

Gas flow at the Walnut Street well, where the gas was shown to be emerging from the Upper Freeport coal, was increased by approximately a factor of ten by lowering the groundwater pressure above the Upper Freeport coal by 75 psi. A commercial gas removal device, the Methane Buster™, was found to increase the volume of gas that could be extracted, but its operation required continuously pumping out the water to reduce the hydrostatic pressure. The biggest costs associated with this solution would be those associated with the required treatment of the brine water. Because there does not appear to be marketable amounts of gas, there would be no monetary return to offset these costs and this would be an expensive option. It was noted that gas volume decreased from 50 to 35 ft<sup>3</sup>/hr at the 4805 Second Street well while the water was being pumped and the Methane Buster™ was being tested at the Walnut Street well. This exemplified the complex interconnectivities and migration pathways, and showed that increasing methane gas extraction from one point source may reduce gas flows at others.

Gas in the permeable Buffalo sandstone is close to the surface, less than 20 feet deep, based on observations at the Borough garage well, and may account for the widespread methane gas problem in the 4700 and 4800 blocks of Penn Way and Second Street. Given the results above, it may be possible to reduce or eliminate the gas problems in this area by drilling wells into the Buffalo sandstone and producing the accumulated gas. This option may require pumping and treating a limited amount of water in the Buffalo sandstone.

Hydrogen sulfide (H<sub>2</sub>S) was present in measurable amounts in a few wells that have low formation pressures and low flow rates, and is presumably the source of the rotten egg smell periodically reported by residents over the last 40 years. The human nose can detect extremely low (parts per billion) concentrations of H<sub>2</sub>S. The occurrence of H<sub>2</sub>S appears to be limited primarily to the 4700 and 4800 blocks of Second Street and Penn Way. The H<sub>2</sub>S was only present at measurable concentrations inside the confinement of the wells themselves, not in the open air. The most likely source of the H<sub>2</sub>S in some wells is the bacterial digestion of organic materials that have leaked into the shallow strata or were dumped in the wellbores when they were open to the surface. Natural gas well brines and water that drains from local coal mines

frequently contain sulfate. In such an environment, sulfate-reducing bacteria can thrive and produce hydrogen sulfide ( $H_2S$ ) when they digest organic substances. One would need to be able to predict vertical movement of organic debris within the wellbores in order to predict  $H_2S$  production in this scenario.

A relatively high concentration of  $H_2S$  was found in one well, and was apparently associated with the well-cleaning exercise. The  $H_2S$  peaked a month or two after the well was cleaned; when the high concentration was observed, the well was capped and kept closed until a  $H_2S$  filtration cartridge was installed. Again, the  $H_2S$  was only present at measurable concentrations within the confined wellbore space, not in the open atmosphere, and the well had a low flow rate of 6.5 ft<sup>3</sup>/hr, a low well head pressure of 3.5 psi, and was filled with water to within 17 feet of the surface, creating a wellbore volume of only 7.2 ft<sup>3</sup> in the 10-inch surface pipe. No measurable hydrogen sulfide has been found in the well for the last six months.

## **Mitigation Options**

Due to the complex network and variety of old wells and the diversity of geologic formations underlying the village of Versailles, there is no single solution that will completely eliminate the methane gas problem. Mitigation options are provided that should reduce the risk to public health and safety; estimated costs are provided below to assist the Borough Council and residents in determining future actions and funding requirements. The primary recommendation includes various venting options, in-home methane monitoring, and new city ordinances. In the unlikely event that this approach is not adequate, a drilling option is provided. For each option, labor and material costs are provided, based on data from "Facilities Construction Cost Data" by R. S. Means (2005) and standard engineering practices. Costs were converted to 2007 values by increasing line items by 10% during the calculations. Due to the numerous uncertainties and unknowns, the costs were estimated conservatively to allow for contingencies, and should provide a sound basis for decision making. More detailed costs will need to be developed, on a case-by-case basis, once one or more of the remedial approaches are selected. It should be noted that no single approach will mitigate all of the stray hydrocarbon gas problems within Versailles. A remedy that works for one building or area may not work on all buildings or all areas. The final remedy will undoubtedly require implementation of several remedial options.

As a first, readily-implemented, cost-effective step, all existing vents should be inspected and repaired or replaced, as needed, as many of them have deteriorating parts, have been removed, contain obstructions (e.g., bird nests), have an ineffective seal with the ground, or are of insufficient height to ensure that gas is vented above adjacent structures. The cost for this option ranges from a few tens of dollars up to over several thousand dollars, per site, based on the extent of repairs.

Investigations should be initiated, at a minimum, at the 14 sites where leaking gas was apparently associated with abandoned wells, to determine if excavation and venting is appropriate. Two options are presented: a non-drilling option and a drill (and clean out debris) option. At some of the sites, due to the location of the well, ventilation trenches may be more appropriate than a vent placed directly over the well.

It is also recommended that a methane detector be installed in each building within the study area. Methane-specific alarms utilizing remote sensors and separate control boxes with audible and visual alarms are recommended for installation. The remote sensors should be installed near the ceiling in the lowest level of the structure by a qualified electrician, and the control box should be installed in the main area of the structure where the audible and visual alarms can be easily recognized. The cost per unit for these alarms ranges from \$250-300, not including installation costs. If the alarms indicate that methane is leaking into the structures, then one of several options to isolate the structures from subsurface methane would have to be installed. It is obviously not possible to estimate how many units would need to be treated in this manner, or how many units would be best treated using one method or the other, since such decisions have to be made on a site-specific basis.

The Borough should consider passing ordinances to ensure that gas does not accumulate under any new structures that are constructed in the Borough. Examples of ordinances from localities in California that have a similar problem have been provided as an appendix to the Final Report. The Borough should also consider acquiring portable methane detectors, and have the supplier provide training on how to calibrate and maintain the instruments. Furthermore, considering how useful magnetometry proved to be in locating the abandoned wells, the PA DEP should consider acquiring one or more magnetometers for use at sites throughout Pennsylvania. NETL personnel can train PA DEP personnel on how to use the devices and process the data.

Finally, two potential long-term strategies are discussed. One strategy involves removing hydrocarbon gas in the subsurface and using it as a resource to preventing future migration of the gas in the subsurface. It focuses on degasifying the Buffalo sandstone, which apparently has, or is, receiving gas from deeper rock formations, and may be responsible for leaking gas in the area within the 4700 and 4800 blocks of Penn Way and Second Avenue. Some initial drilling would be necessary to determine if this approach is feasible, whether water treatment would be necessary, and how much gas can be produced in this manner. Unfortunately, there is a good chance that some water will have to be pumped out and treated, which would make the option significantly more expensive. If it is found to be feasible, vertical and/or horizontal wells could be used to degas the strata. Another strategy would be to tie together, at the surface, all or most of the existing wells and vents into a central collection and distribution system. Because these options require additional studies before they can be assessed as being feasible, they are not discussed in detail here but are discussed elsewhere in the report.

## **Some Specific Remediation Measures and their Estimated Costs**

### **Install Ventilation Trenches in Areas Where Stray Hydrocarbon Gas Has Been Detected in Soils within 5-10 feet of a Structure**

Stray hydrocarbon gas within 3 feet of a structure typically results in a notice from the natural gas utility company that gas service will be terminated due to the risk of gas entering the structure. Ventilation trenches are typically 2-4 feet wide and installed to a depth of 3-4 feet below grade. The trenches are lined with 2B gravel with 4-6 inch diameter perforated PVC pipe placed over the length of the trench. The pipe is placed in the trench so that two sets of perforations face downwards at roughly 45°. One end of the PVC pipe in the trench would be

fitted with a vertical vent, no less than 10 feet in height. The other end of the pipe in the trench would be fitted with a 90° PVC elbow and capped to be flush with the surface. The vent should be fitted with a stainless steel wind driven turbine. This section could be fitted with a powered fan, if improvement in ventilation is required. The trench could be designed around the entire perimeter of a structure or along one or more sides. The length of the trench would be site specific and dependent on the distribution of stray hydrocarbon gas in the subsurface. Ongoing monitoring in the vicinity of the ventilation trench would be required for some period of time to determine effectiveness.

Cost per Trench (one trench on one side of a building): \$10,000

### **Install Sub-slab Pressurization Systems in Structures Known to Contain Stray Hydrocarbon Gas**

Sub-slab pressurization (SSP) systems create a positive pressure, clean air buffer below the structure and effectively counteract the low-pressure field created naturally by the structure. These systems are recommended for structures rather than conventional sub-slab depressurization (SSD) systems in areas where the concentration and volume of gas is significant or unknown. SSD systems create a negative pressure below the slab, drawing more gas towards the structure and through the vent. They are very effective to mitigate low concentrations and volumes of stray gas. However, in areas where the concentration and volume of stray hydrocarbon gas is significant, these systems can be overcome, resulting in contaminated air entering the structure.

A mechanical fan that directs outside air through vertical vent(s) into the sub-slab material powers the SSP systems. These systems are only effective if the material below the slab is permeable to evenly distribute the air to the area below the slab. In materials that are not sufficiently permeable, horizontal extension(s) of the vertical vent and replacement of the impermeable material with permeable gravel may be necessary to improve system performance. Prior to installation of the SSP systems, construction gaps and cracks in the concrete floor must be repaired with hydraulic or non-shrinking cement to prevent short-circuiting of the air.

Cost per System: \$3,000

### **“Engineered” Venting of Leaking Wells**

This option requires venting of any well found to be leaking gas within the Borough. Many such wells were found using the magnetometer and methane surveys to be leaking gas below the ground surface – potentially allowing gas to migrate horizontally within the soil to structural foundations. The term “engineered” refers to the fact that something is being done to the leaking well to get the gas out of the ground and away from structures. Two options are presented: a non-drilling option and a drill and clean option. Both options assume the gas is being emitted through the casing in the old well and not from the annulus (space between the casing and borehole) of any casing remaining in the ground.

### **Non-Drilling Option**

In the non-drilling option, the gas-emitting well would be uncovered by digging out the area around the well. Depending on the depth to the top of the well, digging may be accomplished by hand or may require power equipment. Once exposed, a passive or blower-equipped vent would be installed on to the existing well casing. The non-drilling option is similar to what has previously been done to the wells within the Borough. This allows the gas to escape, reducing wellbore pressure. As more wells are vented this way, the likelihood that gas will migrate horizontally decreases. Because the wellbore may have partial blockage at depth or may be leaking through corroded holes or the annulus of the remaining casing, this method does not insure that all of the gas will be vented – gas could still migrate into structures. Once installed, the vents should be periodically checked to ensure no gas is leaking around the vents and that the vents are open to the atmosphere.

Average per Well Cost:

\$1,300

### **Drilling Option**

The drilling option is similar to the non-drilling option except that existing gas-emitting wells would be cleaned out to a depth sufficient to ensure that gas entering the wellbore will be contained by the vent. Some restrictions, other than cost, may limit this option, such as accessibility due to the proximity to buildings and power lines. Under this option, the best scenario would be to clean out the existing well, set casing to ensure that gas does not leak into geologically higher formations, and then vent the well. Costs for this option are more expensive initially for the drill rig, casing, and open-hole packer assembly. Some of the wellbores are known to be clogged with debris, and removing such debris is time-consuming and expensive because of the varied nature of the materials thrown in the wells. (The two wells cleaned out as part of this project had formation bridges across the wellbore, contained old bricks, pieces of wood, metal window parts, and cement, as well as wellbore integrity problems due to prolonged exposure to water.) With this option, there is a much lower probability that the gas will migrate towards a structure, because the installed casing is more apt to prevent the methane from entering the shallower permeable geologic formations or the soil zone than the existing corroded casing left in the wellbore. If drilling is done, it would be best to use a cable tool rig without the addition of water to the wellbore, rather than a rotary rig and water as a drilling fluid. This approach should be more efficient if there is debris in the well and is less likely to stimulate the generation of H<sub>2</sub>S.

Average per Well Cost:

\$30,000



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